INDOOR AIR QUALITY ASSESSMENT

Penn Brook Elementary School
68 Elm Street
Georgetown, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
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Background/Introduction

At the request of Mike Donahoe, Facilities Director, Georgetown Public Schools, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality concerns at the Penn Brook Elementary School, Georgetown, MA. On March 14, 2002, a visit was made to the school by Cory Holmes, Environmental Analyst in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) program, to conduct an assessment. Mr. Holmes was accompanied by George Sylvester, Penn Brook Custodian, during the assessment.

The school is a one-story brick structure built in the early 1970's. The school is in the process of replacing exterior doors. A new roof was reportedly installed within the last five years. The school contains general classrooms, science classrooms, a computer lab, music room, several resource rooms, library-media center, gymnasium, office space, art room, kitchen and cafeteria. Windows throughout the building are openable.

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551.

Results

The school houses students grades 2-5. It has a student population of approximately 475 and a staff of approximately 40. Tests were taken during normal operations at the school and results appear in Tables 1-4.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were elevated above 800 parts per million parts of air (ppm) in eighteen of twenty-seven areas surveyed, indicating inadequate ventilation in these areas of the school. It is important to note that a number of areas were sparsely populated or had windows open at the time of the assessment, which would be expected to contribute to reduced carbon dioxide levels. Of particular note were classrooms 4, 5, 6, 19 and the library, which all had elevated levels of carbon dioxide (i.e. >800 ppm) without occupancy.

Fresh air in classrooms is supplied by a unit ventilator (univent) system (see Picture 1). Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building (see Picture 2) and return air through an air intake located at the base of each unit (see Figure 1). Fresh air and return air are mixed, filtered, heated and provided to classrooms through a fresh air diffuser located in the top of the unit. Univents were found deactivated in a number of classrooms (see Tables/Picture 3). Obstructions to airflow, such as books, papers, and desks were seen in a number of classrooms (see Pictures 1 & 4). In order for univents to provide fresh air as designed, they must remain free of obstructions. Importantly, these units must be activated and allowed to operate.

The mechanical exhaust ventilation system in classrooms consists of grated, wall-mounted exhaust vents (see Picture 5). Exhaust vents from individual classrooms are drawn into a common duct above the ceiling in hallways to be expelled from the building

via an exhaust grill at the terminus of each hallway (see Picture 6). At the time of the assessment a number of exhaust vents were not operating (see Tables), which can indicate that they were deactivated or were mechanically malfunctioning (e.g. motor burnt out, broken belt).

Occupants in the 4th grade area of the school (classrooms 4-9) expressed concerns of poor air quality. It was determined that one univent in each section of the school also serves as the master control for the exhaust fan for that section. The highest carbon dioxide reading was measured in classroom 5 (2,270 ppm) while it was unoccupied, indicating little or no airflow. The univent that controls exhaust ventilation in classrooms 4-7 is located in classroom 5. This univent was deactivated, which in turn deactivated the exhaust fan for this area. Without dilution by the introduction of fresh air via the univent, and removal by the exhaust ventilation system, normally occurring environmental pollutants can build up and lead to indoor air complaints.

Ventilation in the gymnasium, library-media center and cafeteria is provided by ceiling mounted air handling units (AHUs) (see Picture 7). Fresh air is distributed via ductwork connected to ceiling-mounted air diffusers. The amount of fresh air drawn into the units is controlled by moveable louvers connected to an activator motor that adjusts to alter fresh air intake to maintain temperature. School maintenance staff reported that the AHUs for the gymnasium and library are seldom used.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a univent and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air

from the room. The date of the last balancing of these systems was not available at the time of the assessment. It is recommended that HVAC systems be re-balanced every five years (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (BOCA, 1993; SBBRS, 1997). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated

temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches.

Temperature measurements ranged from 70° F to 75° F, which were within the BEHA comfort guidelines. The BEHA recommends that indoor air temperatures be maintained in a range of 70 ° F to 78 ° F in order to provide for the comfort of building occupants. Temperature control complaints in a number of classrooms were expressed to BEHA staff during the assessment. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. It is also difficult to maintain temperature without operating the ventilation system as designed (e.g. deactivating univents and exhaust fans).

The relative humidity measured in the building ranged from 25 to 35 percent, which was below the BEHA recommended comfort range. The BEHA recommends a comfort range of 40-60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Several classrooms had a number of plants. Moistened plant soil and drip pans can be a source of mold growth. A window planter with decaying plant matter and old potting soil was seen on the windowsill in the teacher's lounge (see Picture 8).

Classroom 24 had plants on paper plates on top of paper towels that were saturated with water (see Picture 9). Plants should be equipped with drip pans. Paper plates and towels are porous materials that can be colonized by microbial growth, especially if wetted repeatedly. In addition, the lack of drip pans can lead to water pooling and mold growth on windowsills. Plants are also a source of pollen. Plants in several classrooms were noted near univent air diffusers (see Picture 10). Plants should be located away from the air stream of ventilation sources to prevent the aerosolization of mold, pollen or particulate matter throughout the classroom.

The absence of a gutter/downspout system along the roof eave to direct rainwater away from the base of the exterior walls (gutters are only installed over exterior doors) was noted. After rainstorms, the exterior walls are saturated with moisture. Rainwater runs off the roof onto the ground at the base of the building. This runoff has created a trench parallel to the base of the wall, which allows rainwater and melting snow to pool against the foundation and the exterior wall of this wing. Splashing water along the edge of the building wets the base of exterior walls creating a characteristic stain (see Picture 11). Growth of moss on exterior brickwork (see Picture 12) is another indication of chronic moisture exposure from rainwater. Moss growth also holds moisture against brickwork. North-facing corners and walls of this building are particularly vulnerable to moisture for extended periods of time, since the brick is not dried out by exposure to direct sunlight. Excessive exposure to water of exterior brickwork can result in damage over time. During winter weather, the freezing and thawing of moisture in bricks can accelerate the deterioration of brickwork. Exacerbating moistening of exterior brickwork

is the accumulation and falling of snowdrifts from the roof. School staff reported that significant amounts of snow sliding from the peaked roofs damage gutters.

Moss growth was observed on the inner lip of univent air intakes (see Picture 13). The design of the fresh air intakes allow for water and debris accumulation inside the grilles, which can in turn be drawn into univents and distributed into occupied areas. In several areas around the building, small trees/stumps and other plants were growing against the foundation and clinging plants were noted on exterior walls (see Pictures 14 & 15). The growth of plants/roots against the exterior walls and along the foundation can bring moisture in contact with wall brick and eventually lead to cracks and/or fissures in the foundation below ground level. Clinging plants can cause water damage to brickwork by inserting tendrils into brick and mortar. Water can penetrate into the brick along the tendrils, which can subsequently freeze and thaw during the winter. This freezing/thawing action can weaken bricks and mortar, resulting in wall damage.

A bird feeder was mounted directly outside a classroom over the window and univent fresh air intake (see Picture 16). Accumulated bird waste was observed on the windowsill (see Picture 17). Birds can be a source of disease, and bird wastes and feathers can contain bacteria and fungi, which can be irritating to the respiratory system.

Other Concerns

The media center office contained a lamination machine. Lamination machines can produce irritating odors during use. The opposite side of the media center office had a wall-mounted exhaust vent. BEHA staff recommended that the lamination machine be re-located to this area to help minimize heat and odors produced during use.

Occupants expressed concern over the dirt/dust accumulation on carpets and floors in classrooms and hallways. Also of note was the amount of materials stored inside classrooms. In many areas, items were observed piled on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Dust can be irritating to the eyes, nose and respiratory tract. Also, dust becomes more readily aerosolized in a low relative humidity environment. For these reasons, items should be relocated and/or cleaned periodically to avoid excessive dust build up.

Carpeting in several areas was extremely worn and damaged (e.g. library and Principal's office) (see Picture 18). School staff reported that these carpets were installed during the original construction of the building, which would make them approximately thirty years old. Disintegrating textiles can be a source of particulates, which can be irritating to the eyes, nose and throat. Carpet fibers/particulate matter can be entrained and suspended in air by univents and/or AHUs.

The computer room contained a window-mounted air conditioner. These units are equipped with filters, which should be cleaned or changed as per the manufacturer's instructions to avoid the build up and re-aerosolization of dirt, dust and particulate matter.

Classroom 26 had a hole/cracks in the wall to allow for pipe penetration. Holes in walls, missing or broken ceiling tiles and open access panels are breaches of the building envelope and provide a means of egress for odors, fumes, dusts and vapors.

Conclusions/Recommendations

The solution to the indoor air quality problem at the Penn Brook Elementary School requires attention in several areas. The combination of the general building conditions, maintenance, work hygiene practices and the age/condition of ventilation equipment, if considered individually, present conditions that can degrade indoor air quality. When combined, these conditions can serve to further negatively affect indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons a two-phase approach is required, consisting of **short-term** measures to improve air quality and **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns.

The following **short-term** measures should be considered for immediate implementation:

1. Develop a clear line of communication between the maintenance department and school personnel for prompt remediation of temperature and/or ventilation concerns/complaints. This can be done by establishing a written request system administered by a single responsible person. Classroom occupants should report temperature extremes immediately to school administration/maintenance and refrain from deactivating equipment.
2. To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation *operate continuously* during periods of school occupancy independent of classroom thermostat control.

3. Consider having the ventilation system balanced by an HVAC engineer every five years (SMACNA, 1994).
4. Remove all blockages from univents to ensure adequate airflow. Clean out interiors of univents regularly.
5. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
6. Remove plants from univents. Ensure plants have drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary. Discard decaying plant matter and potting soil in teacher's lounge.
7. Remove plant growths against the exterior wall/foundation of the building to prevent water penetration.
8. Clean exterior walls and univent air intakes of moss and debris.
9. Relocate bird feeder in Picture 16 away from classroom window and univent air intake. Clean area of all bird wastes and disinfect with an appropriate antimicrobial.

10. Consider relocating lamination machine in media center office to below exhaust vent. Occupants should ensure exhaust ventilation is activated prior to use.
11. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning of classrooms. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
12. Change filters for univents, AHUs and AC units as per the manufacture's instructions or more frequently if needed.
13. Seal wall cracks/holes in classroom 26 to prevent the egress of dirt, dust and particulate matter from the wall cavity into occupied areas.

The following **long-term measures** should be considered:

1. Based on the age, physical deterioration and availability of parts for ventilation components, the BEHA strongly recommends that an HVAC engineering firm fully evaluate the ventilation systems.
2. Consider replacing damaged/worn carpeting in the library and principal's office to prevent the aerosolization of carpet fibers.
3. Examine the feasibility of increasing mechanical supply and exhaust ventilation.
4. Contact an electrical engineer to reconfigure the control system so that univents and exhaust vents are controlled separately.
5. Examine the feasibility of installing a gutter/downspout system to parts of the building that lack them.
6. Contact an architectural/roofing firm to examine ways to prevent the accumulation and sliding of snowdrifts from the roof.

7. Examine the feasibility of replacing or modifying the exterior of univent fresh air intakes to prevent the accumulation of moss and debris.

References

BOCA. 1993. The BOCA National Mechanical Code/1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0

SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

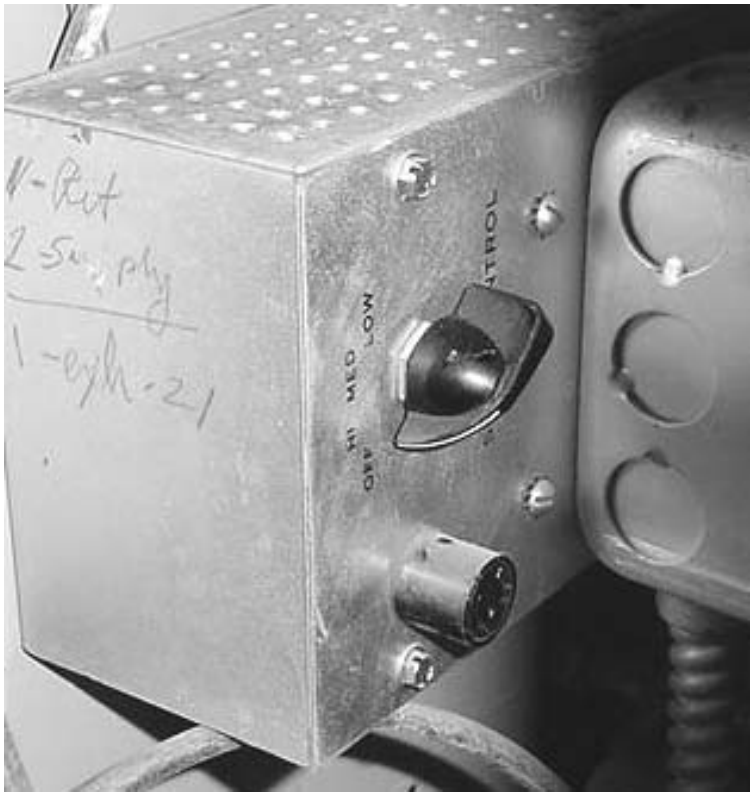
Picture 1

Classroom Univent: Note Items on Top and In Front of Unit, Obstructing Airflow

Picture 2

Univent Fresh Air Intake

Picture 3



Univent Control Switched to Off Position in Classroom During School Occupancy

Picture 4

Univent Obstructed by Various Items

Picture 5

Wall-Mounted Exhaust Vent in Classroom

Picture 6

Exhaust System Terminus above Exterior Door

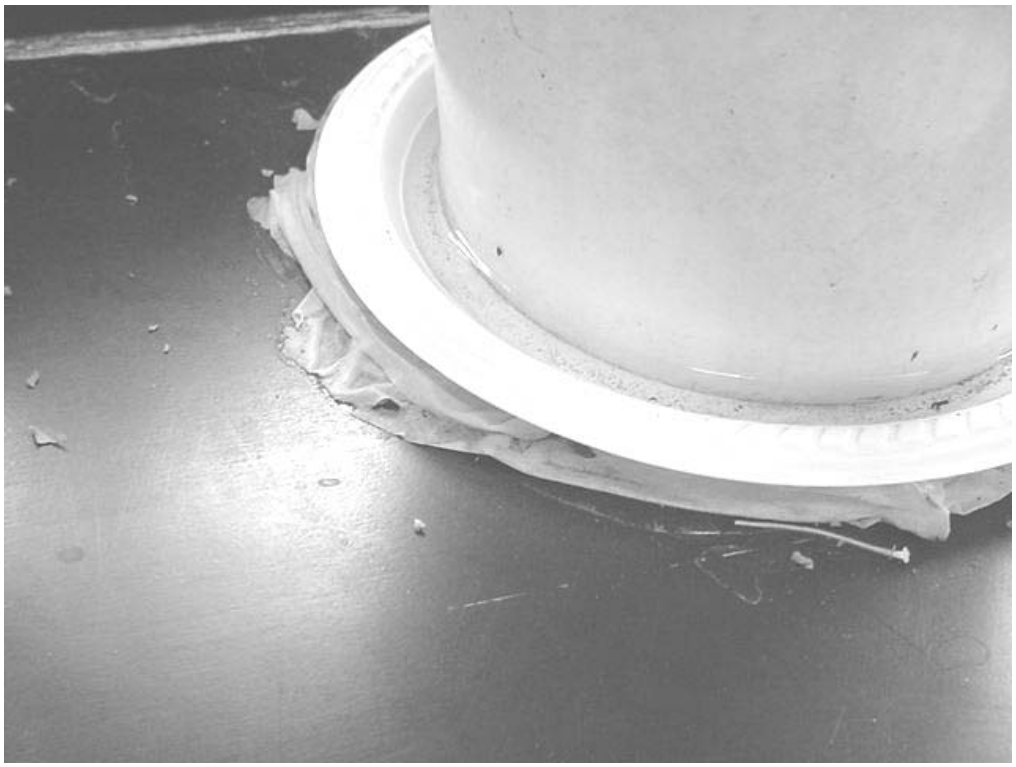
Picture 7

Ceiling-Mounted AHU and Air Diffusers for Library-Media Center

Picture 8

Window Planter with Decaying Plant Matter and Potting Soil in Teacher's Lounge

Picture 9



Plant on Wet Paper Towels and Paper Plate with Standing Water in Classroom

Picture 10

Plants on and above Classroom Univent Air Diffusers

Picture 11

Trench and Wall Staining alongside Front of Building

Picture 12

Moss Growth on Exterior Wall

Picture 13

Moss Growth in Univent Fresh Air Intake (Exterior)

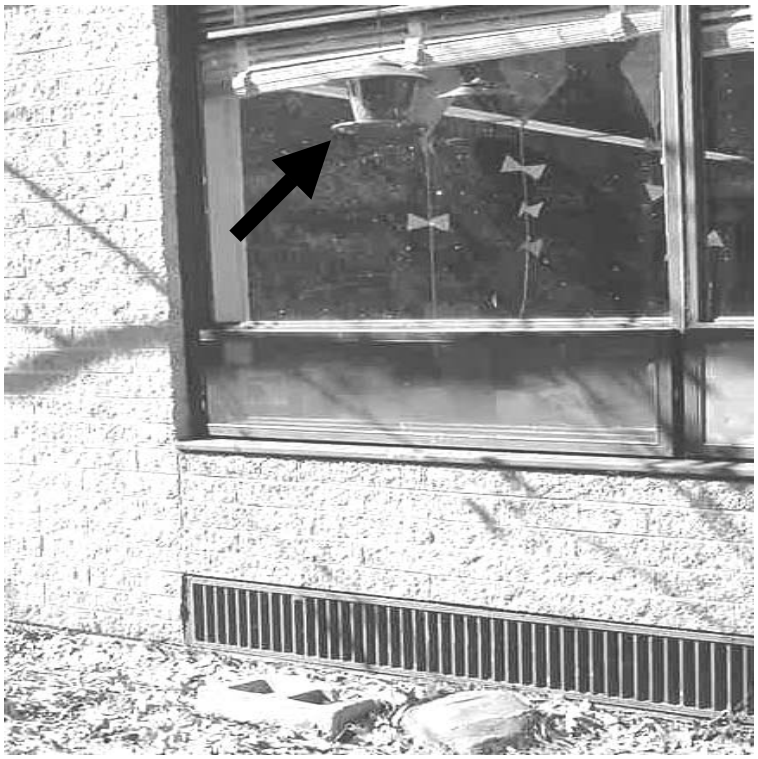
Picture 14

Small Trees/Roots Growing against the Foundation

Picture 15

Clinging Plants on Exterior Wall

Picture 16



Bird Feeder Mounted over Window/Univent Air Intake

Picture 17

Bird Wastes on Classroom Windowsill (Beneath Bird Feeder in Preceding Picture)

Picture 18

Damaged/Worn Carpeting in Principal's Office

TABLE 1

Indoor Air Test Results – Penn Brook School, Georgetown, MA – March 14, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	358	65	33					Clear, sunshine, windy
Music Room	1070	72	35	2	Yes	Yes	Yes	22 occupants gone ~10 mins., window open
26	1000	73	33	20	Yes	Yes	Yes	Wall cracks
24	1079	73	31	22	Yes	Yes	Yes	Items on/in front of univent, plants in standing water-on paper plates/towels-saturated
20	945	72	31	1	Yes	Yes	Yes	(20+) occupants gone ~5 min., items on univent, door open
23	915	70	29	20	Yes	Yes	Yes	Window open
Library	816	74	31	0	Yes	Yes	Yes	Ceiling fans, AHU-not operating
18	1000	73	31	2	Yes	Yes	Yes	Univent blocked top/front with items
19	900	72	31	0	Yes	Yes	Yes	Accumulated items on flat surfaces
16	760	71	29	0	Yes	Yes	Yes	

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Penn Brook School, Georgetown, MA – March 14, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Computer Room	414	71	25	0	Yes	Yes	Yes	Window mounted air conditioner
Media Office	756	73	30	2	No	No	Yes	Lamination machine-recently relocated under exhaust vent
12	912	72	30	22	Yes	Yes	Yes	Items on univent, univent rattling
11	879	72	29	20	Yes	Yes	Yes	Window and door open, plants/items on univent
10	650	74	28	22	Yes	Yes	Yes	Window open, items on univent
9	798	71	27	0	Yes	Yes	Yes	Window open
8	852	72	28	23	Yes	Yes	Yes	Window and door open, flowering plant on univent, items on/in front of univent
6	860	73	30	0	Yes	Yes	Yes	(23) occupants gone 5 min., accumulated items, window open
5	2270	72	35	0	Yes	Yes	Yes	Univent deactivated, plants on/over univent
3	1210	72	31	5	Yes	Yes	Yes	Items on/around univent, door open

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TABLE 3

Indoor Air Test Results – Penn Brook School, Georgetown, MA – March 14, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
4	1510	73	33	0	Yes	Yes	Yes	Exhaust off
1 – Art Room	836	73	31	20	Yes	Yes	Yes	Items on/in front of univent, plants near univent, kiln-no exhaust-not used
Gym	732	71	30	24	Yes	Yes	Yes	2 AHU, wall mounted exhaust
Lobby								plants on univent
Cafeteria	1100	73	32	~125	Yes	Yes	Yes	
Teachers' Dining Room	914	72	30	4	Yes	No	Yes	Window planter-decaying plant matter/potting soil
Main Office	782	73	28	5	Yes	Yes	Yes	
Assistant Principal's Office	753	75	28	1	Yes	Yes	Yes	Air conditioner
Guidance Office	532	75	28	0	Yes	Yes	Yes	Univent off-plants on univent

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TABLE 4

Indoor Air Test Results – Penn Brook School, Georgetown, MA – March 14, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Perimeter Notes				Plant growth in/near univent intakes, moss growth-walls, reports of snow build up around univent intakes, some areas missing gutters-reported problems with snow falling off roof-damaging gutters, moss growth in univent intakes, bird feeders hung over air intakes, clinging plants on exterior wall				

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